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*Chronology of submarine paleoseismology events using radionuclides*

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Submarine Paleoseismology is the study of the timing, location and size of prehistorical earthquakes at sea. The interpretation of the chronology model of a sedimentary record is very essential for studies ON and OFF fault because allows to interpret and calculate slip rates, obtain the ages of submarine landslides and turbidites triggered by earthquakes, as well as obtaining earthquake recurrence intervals. Therefore, it is necessary to understand the methodological bases and main applications of the different techniques that are commonly used to establish the age of paleoseismology events using the quantification of physical, chemical, biological or geological parameters depending on time. The aim of this presentation is to present in detail the main procedures as well as the limitations of the two most common radiometric techniques used in submarine environments:  $^{210}\text{Pb}$  and  $^{14}\text{C}$  based on selected published examples.

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*Submarine paleoseismology: An overview of near fault & off-fault investigations at sea*

Paleoseismology is the study of the timing, location and size of Holocene earthquakes. Most of the largest earthquakes are located in submarine areas, essentially along subduction zones and other plate boundaries. Since the deadly 2004 Sumatra-Andaman Islands earthquake (Mw 9.3) and subsequent tsunami there has been increasing interest to know how often these marine events occur in order to raise public awareness of seismic hazards and to mitigate the effects of future earthquakes. Because traditional onland techniques are not feasible in sub-aqueous environments, development of new methods and technological aspects are a key issue in submarine paleoseismology. State of the art methodologies integrate the most advanced tools in marine geosciences covering different scales of resolution. Acoustic mapping techniques, such as swath-bathymetry and sidescan sonar data, allow identifying the geomorphic evidence of active faults, such as seafloor ruptures, folds, fault scarps and fault traces. Sub-seafloor seismic imaging methods, ranging from high-resolution sub-bottom profiler (uppermost tens of meters of penetration) to multichannel seismic data (several km of penetration) allow to detect the stratigraphic evidence of past seismic activity, such as displaced seismic horizons, folded and faulted reflectors, zones of shearing, and discontinuities. Pre-stack depth migration of MCS profiles yield a corrected geometry of seismic reflectors, and thus, may help to calculate fault seismic parameters. "In situ" direct fault observation and sampling can also be carried out by using submersibles and remotely operated underwater vehicles. Sediment sampling methods and subsequent analyses (texture, sediment composition, physical properties and age), allow identifying, characterizing and dating coeval submarine mass transport deposits triggered during seismic events. Primary paleoseismic evidence based on direct fault investigations enables the characterization of active submarine faults and their paleoseismic parameters (i.e. length, segmentation, fault dip, slip rate, maximum magnitude earthquake, and elapsed time since last event). Secondary paleoseismic evidence based on identification and age of earthquake-triggered landslides and turbidite deposits may help to obtain the recurrence rate of large magnitude (Mw > 6) earthquakes occurred in a given region. An overview of on-fault and off-fault investigations at sea in different geodynamic settings, from low-rate convergence to subduction margins, will be presented.

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#### *Characterization of Submarine Earthquake Sources and Paleoseismic Records on the New Zealand Continental Shelf and Slope*

The plate boundary active deformation zone in the New Zealand Region is essentially submarine, and includes 1) back-arc extensional deformation in the Bay of Plenty; 2) compressional deformation along the Kermadec-Hikurangi oblique subduction margin to the east of the North Island and the Fiordland-Puysegur Margin to southeast of the South Island; and 3) transpressional deformation over the continental shelf. Because of favourable conditions for marine sedimentation during the last 20,000 years, the location and activity of the offshore faults are well recorded at and beneath the seabed. Furthermore, good imaging of the last two transgressive surfaces (120 and 20 kyrs) and a well documented tephra (volcanic ash) record provide excellent means to constrain the timing of faulting and estimate the fault long-term slip rates.

We developed three conceptual approaches for building a submarine paleoseismic record and applied them to the New Zealand submarine region in order to improve our understanding of the offshore seismic hazard at a national scale. These studies are supported by extensive multibeam bathymetry coverage, multi-channel high-resolution seismic reflection data and a rich collection of sediment cores which together provide key geological and geophysical material to develop and implement our methodology of paleoseismic and marine hazard research.

1) We systematically identified and characterised submarine seismic sources from the fault traces and their subsurface expressions as well as from their distribution, geometry and interrelationships. Slip rates are estimated by measuring the fault displacement of recent stratigraphic or geomorphological markers, by estimating their contribution to the regional relative plate displacement. The maximum likely earthquake magnitude  $M_w$ , co-seismic displacements and return time interval for each source are subsequently derived using a New Zealand specific empirical regression relating rupture dimensions to earthquake moment magnitude. This information feeds into the National Seismic Hazard Models.

2) We constrained the history of fault growth and fault rupture along individual faults using high-resolution seismic stratigraphy of the post-last glacial period. In particular we are able to reconstruct the long-term accumulation of fault displacement from repeated earthquakes by measuring offsets in marker horizons along the fault plane. Using varying scales of temporal resolution we constrain the evolution of displacement on a fault system over long time period, down to the distribution and magnitude of slip on a single earthquake. In some instances, where conditions and sedimentation and slip rate are optimal, we were able to document 6-8 individual events over the last 18 kyr.